Internal Motions and Fine Structure of Astronomical Masers : Application to Stellar Astrophysics and High Precision Astrometry(Abstracts of Doctoral Dissertations,Annual Report (form April 1998 to March 1999))

Internal Motions and Fine Structure of Astronomical Masers: Application to Stellar Astrophysics and High Precision Astrometry

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Astronomical masers are important objects which trace gas kinematics in the very vicinity of young stellar objects and in the circumstellar envelopes around evolved stars. These masers consist of many "maser features" with size of about one astronomical unit (AU), which can be detected and precisely measured their positions using very long baseline interferometry (VLBI). In this work, drifts of line-of-sight velocities and apparent positions in time for the individual water vapor maser features have been measured in the circumstellar envelope of the semiregular variable RT Virginis and in the massive star forming region W3 IRS5.

Fig. 1 shows the distribution and three-dimensional (line-of-sight and transverse) motions of water vapor maser features in W3 IRS5. We find that at least two originating points of expansion motions appear near the candidates of newly-formed massive stars (radio continuum sources "a" and "d1"). Both of the expansion motions (outflows) are roughly collimated in the north-south direction. This suggests an important prospect that these massive stars were created by a molecular cloud which collapsed and was divided into several molecular cores with the similar angular momentum vectors with being affected by the magnetic field. This idea has been proposed by several theoretical models. By fitting the three-dimensional kinematics to the spherically expanding flow model, the distance to W3 IRS5 was directly estimated as 1.81 ± 0.10 kpc without any standard candle.

In reality, each maser feature shows fine structure, systematic or random velocity gradient in space. From the statistical analysis, these structures are created by microscopic turbulence in the outflows in the scale of 0.01–0.5 AU. In fact, the two-point correlation function at this scale shows a constant gradient, suggesting "fractal" fashion. Such newly-discovered fine structure as well as its time variation (e.g., acceleration/deceleration motion) will provide important information concerning gas dynamics of outflows and circumstellar disks around young stellar objects and circumstellar envelopes of evolved stars.

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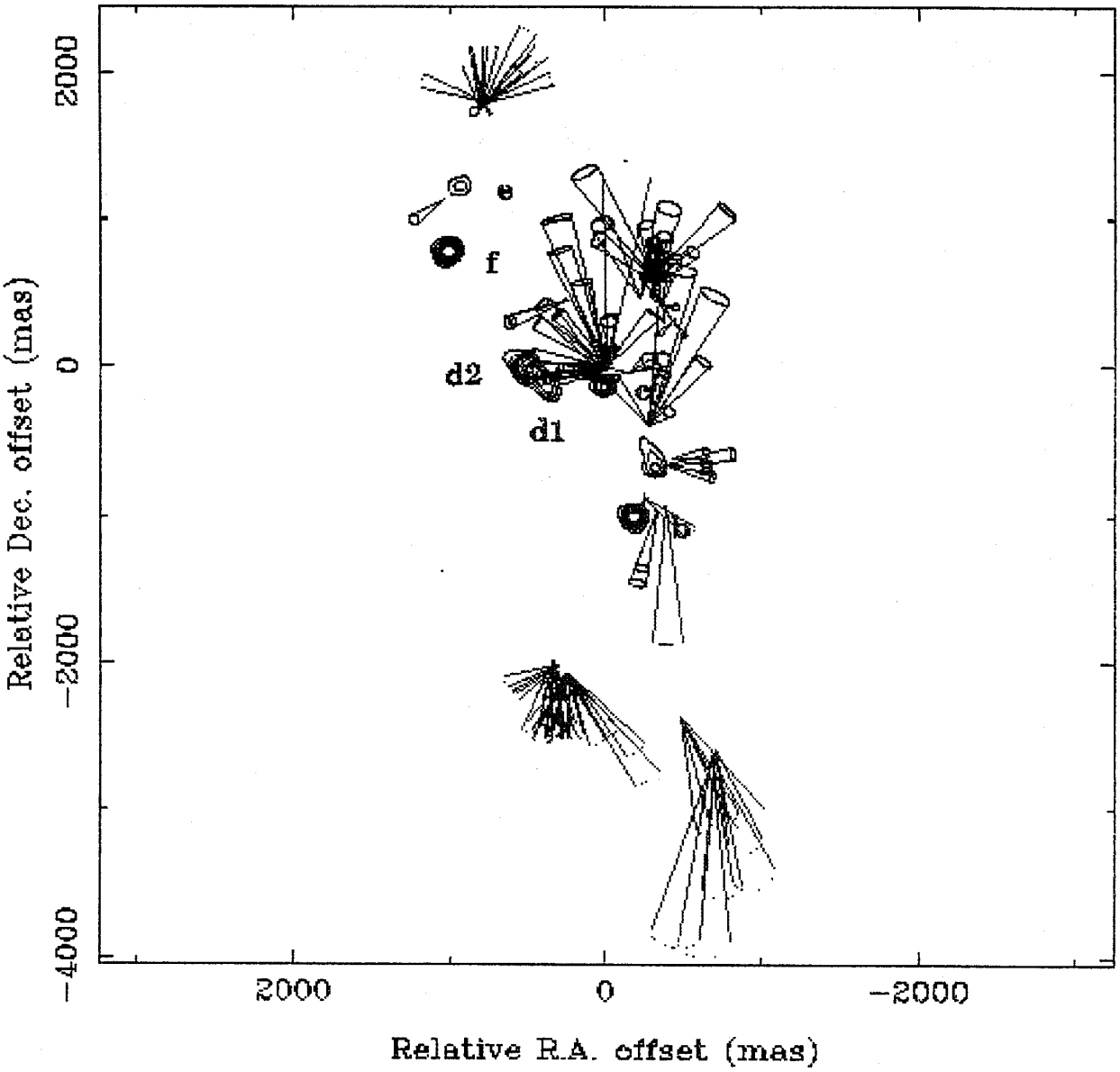

Figure 1: Spatial relation between water maser features and compact radio continuum sources, candidates of the newly-formed massive stars, in the W3 IRS5 region. Origin of the corn shows the maser feature position. Direction and length of the corn show the direction and 325 times magnitude of the proper motion per year, respectively. The corn opening angles are common to all maser features independent of the uncertainty of the motion vector. The radio continuum sources, which were mapped by Claussen et al. (Astrophys. J., **424**, L1-L44, 1994) are shown as contours.